Hemispheric asymmetries for auditory short-term habituation of tones?

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1 Introduction

The sounds of speech are characterized by complex spectral profiles with rapidly changing spectral peaks [1]. The processing of speech thus requires a fine temporal resolution of the auditory system to extract those rapid formant transitions.

Passive listening to rapid (40 ms) frequency changes results in left-lateralized activation of the auditory cortex, while bilateral symmetric activation was observed during longer (200 ms) transitions [2]. There is growing evidence that language disorders such as aphasia or developmental dyslexia are associated with impairments of auditory processing [3]. Psychoacoustic studies indicated a deficit of spectral and temporal auditory resolution in developmental dyslectics [4, 5]. In a recent MEG study the cortical responses to brief and rapidly successive tones were compared between subjects with poor and normal reading abilities. Poor readers demonstrated a significantly smaller response to the second of two tones than normal readers [6].

These results led us to the assumption that a functional hemispheric asymmetry of the auditory cortex regarding its abilities to process rapidly changing acoustical input might contribute to the lateralization of language. In this study we tested the hypothesis that the temporal resolution of the left auditory cortex is better than of the right auditory cortex, as indicated by a stronger auditory short-term habituation in the non-dominant right hemisphere than in the language dominant left hemisphere.

2 Methods

Auditory evoked magnetic fields were recorded with a 37-channel biomagnetic system (MAGNES I, BTi, USA) successively over both hemispheres in 8 healthy right-handed volunteers (four females; age, 22-34 years) as previously described [7]. Two female subjects had to be excluded from further analysis since the goodness-of-fit of individual dipoles was smaller than 95%.

All subjects were strongly right handed as indicated by the Edinburgh handedness inventory [8]. They were native speakers of German and grew up in a monolingual family.

The stimuli consisted of trains of four 1000 Hz sine tones of 20 ms duration each with rise and fall times of 5 ms. The offset-to-onset interstimulus interval between single tones was 200 ms. The intertrain interval between trains of four tones was varied randomly between 4000 and 5000 ms. For each hemisphere, 400 trains of tones were delivered to the contralateral ear with an intensity of 60 dB above the individual hearing threshold. The experimental setup is illustrated in figure 1.

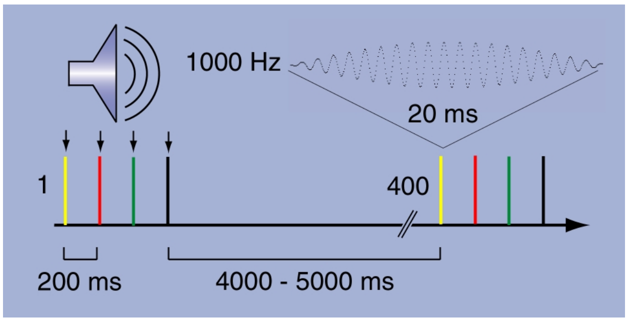

Figure 1: *Illustration of the experimental paradigm.*

Subjects laid on their left or right side and were supported by vacuum cushions to minimize movement during the measurement. They could watch a self-selected video movie and were instructed not to concentrate on the auditory stimulation.

The evoked magnetic fields were averaged off-line, baseline corrected, and filtered with a band-pass filter of 0.01-40 Hz. To localize the neuronal sources of the magnetic field distribution the model of a single equivalent current dipole (ECD) in a spherical volume conductor was applied. The corresponding ECDs of the N100m peaks of the four consecutive evoked responses were selected for further analysis. The percental changes of the latency, the amplitude and the dipole strength between the 1st and the subsequent N100m responses were calculated. All data are presented as mean ± standard deviation. The non-parametric Wilcoxon test was used to compare the results obtained in the left and right hemisphere.

3 Results

All 6 subjects displayed 4 clear N100m responses about 100 ms after onset of each tone. Individual data of one subject is shown in figure 2.

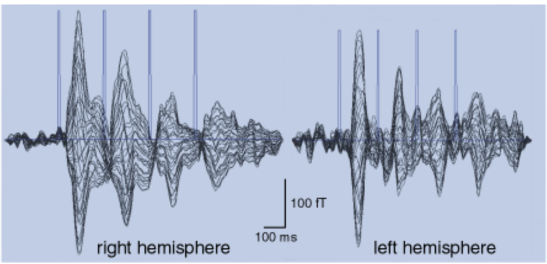

Figure 2: *auditory evoked magnetic fields after stimulation with 4 tones in 1 individual subject.*

The latencies of the 2nd, 3rd and 4th N100m were longer than the 1st N100m in all 6 subjects in the right hemisphere and in 5 of 6 subjects in the left hemisphere. The percental increase in latency between the 1st and the 4th N100m was 37±35 ms and 25±31 ms in the right and left auditory cortex, respectively. The mean latencies for the 4 consecutive N100m responses are displayed in figure 3.

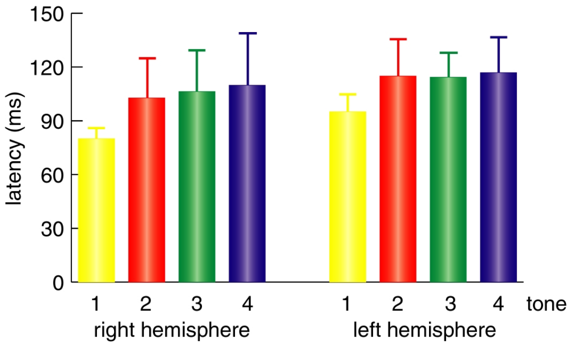

Figure 3: *Latencies of the N100m for tones 1-4 (mean ± SD; n=6 subjects)*

The root mean square of amplitudes (rms) of the 4th N100m was smaller than the rms of the 1st N100m in all subjects in the left hemisphere and in 5 of 6 subjects in the right hemisphere. The rms decreased from 133±50 fT (1st N100m) to 70±8 fT (4th N100m; percental decrease -40±24%) in the right hemisphere and from 117±32 fT to 70±13 fT (-38±9%) in the left hemisphere (figure 4).
The rms reached an asymptotic level already with the 3rd tone. No relevant further decrease of the rms was observed between the 3rd and 4th N100m.

The strength of the current dipole Q decreased from 33±17 nAm (1st N100m) to 28±18 nAm (4th N100m; -17±14%) in the right hemisphere and from 27±10 nAm to 19±5 nAm (-26±26%) in the left hemisphere (figure 5).

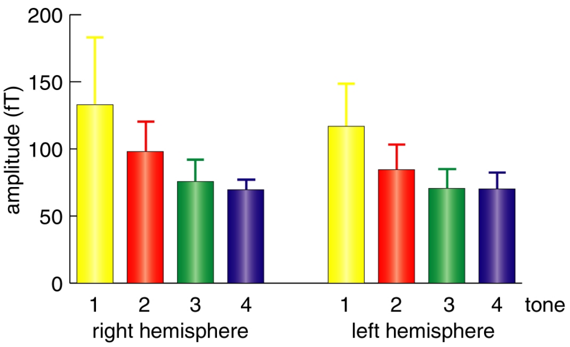

Figure 4: *Root mean square of amplitudes of the N100m for tones 1-4 (mean ± SD; n=6 subjects)*

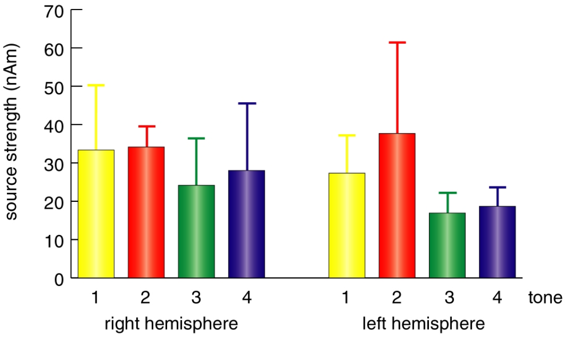

Figure 5: *Source strength for tones 1-4 (mean ± SD; n=6 subjects)*

No significant differences were found between both hemispheres regarding the increase of latency and the decrease of amplitude and dipole strength (Wilcoxon test).
The dipole location changed in the course of the stimulus sequence. The source of the 2nd N100m was shifted in medial and inferior direction in all subjects in the right hemisphere and in 5 of 6 subjects in the left hemisphere compared to the source of the 1st N100m (figure 6).

4 Discussion

Auditory short-term habituation of sine tones during passive listening is characterized by an increase of the latency and a decrease of the amplitude and dipole strength of rapidly successive

N100m responses, similarly in both cerebral hemispheres. These results do not provide evidence for a superior temporal resolution of tones in the left auditory cortex.

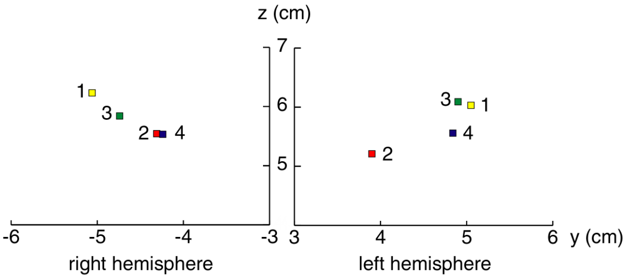

Figure 6: *Mean location of the N100m dipole in medio-lateral direction (y) and in cranio-caudal direction (z) for tones 1-4 (n=6 subjects).*

The reduction of amplitude seen here is similar to the results previously obtained with electric [9] and magnetic recordings [10]. The mechanisms underlying auditory short-term habituation are not entirely clear. Electrical recordings suggest that diminished excitability of the N100 generators after a preceding stimulus, i.e. a refractory process, leads to the observed changes in the response properties of the subsequent N100 [11].

Unexpectedly, we observed a shift of the location of the N100m during the train of 4 tones. The source of the 2nd N100m was on average located at a more medial and inferior position than the source of the 1st N100m. Since there is evidence that multiple and spatially distinct cerebral generators contribute to the N100m, the shift in location observed here might be caused by the different recovery periods of these sub-components as described by Hari et al. [12] and Sams et al. [10].

In summary, this study on the temporal auditory resolution of sine tones provides no evidence of functional hemispheric differences of the auditory cortices that could contribute to the lateralization of language. Since recent MEG studies have shown left-hemispheric lateralization for the processing of vowels [13, 14], future studies have to assess the short-term habituation for speech sounds.

References

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